Strategic Plan for
Pest Management Research & Education in
Southern Sweetpotato Production Systems

Summary of Workshops held October 2001 and
January, February and August 2002

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Executive Summary

The southern states of Alabama, Louisiana, Mississippi, and North Carolina produce close to 75 percent of the U.S. supply of sweetpotato. A wide variety of insects, plant pathogens and weeds are pests in southern sweetpotato production systems, reducing both yield and quality. In 2001, the Department of Horticultural Science at North Carolina State University (NCSU) initiated a series of workshops to develop a strategic Integrated Pest Management research and education plan for the sweetpotato industry in Alabama, Louisiana, Mississippi and North Carolina. The workshops were funded through a grant from the Strategic Agricultural Initiative of the U.S. Environmental Protection Agency, Region 4.

In October of 2001 and January, February and August of 2002, four workshops were held bringing together over two dozen researchers, extension specialists, growers, processors and others to develop a detailed plan for enhancing pest management research and education efforts in sweetpotato production. Workshop participants were motivated by the fact that the sweetpotato industry is facing the potential loss of materials, such as the organophosphate and carbamate insecticides threatened by implementation of FQPA.

The primary insect management challenge, as identified by workshop participants, is soil borne pests for which the development of core IPM tools, such as monitoring methods and economic thresholds, has been minimal. In response, most growers rely on prophylactic insecticide applications. Disease management is challenged by the fact that identification of specific sweetpotato pathogens and development of targeted control tactics has lagged far behind that of other commodities. Growers thus rely on broad-spectrum soil fumigants and post-harvest fungicides as primary management strategies. Workshop participants concurred that weed management methods for sweetpotato are extremely limited.

The strategic plan describes the pest management challenges faced by the industry and recommends a series of goals, strategies and activities for addressing gaps in pest management research and education. The plan highlights critical research needs, including the identification of:

- causal factors associated with insect damage,
- insect monitoring and scouting techniques,
- interactions between weed populations and insect damage,
- the etiology of post-harvest root damage,
- reduced-risk disease management tools,
- techniques for enhancing the health of propagation materials,
- growers' priority weed problems,
- weed-free periods or density thresholds to minimize herbicide use, and
- new sweetpotato varieties resistant to diseases, insects and weed competition.

The plan calls for the evaluation of alternative, preferably reduced-risk chemical and non-chemical control strategies for insects, weeds and diseases. The plan also focuses on developing educational tools which help growers minimize prophylactic pesticide applications and reduce costs.

Background

Sweetpotato production is an important agricultural business in southern U.S. states. The top ranking states are, in order of economic value, North Carolina, Louisiana and Mississippi (USDA 2000). Alabama is the fifth largest producer in the nation. In 1999, these states grew sweetpotatoes on close to 70,000 acres, which represents close to three-quarters of U.S. production. A variety of insects, plant pathogens and weeds are pests in southern sweetpotato production systems, reducing both yields and quality.

In 2001, the Department of Horticultural Science at North Carolina State University (NCSU) initiated a series of workshops to develop a strategic Integrated Pest Management research and education plan for the sweetpotato industry in Alabama, Louisiana, Mississippi and North Carolina. The workshops were funded through a grant from the Strategic Agricultural Initiative of the U.S. Environmental Protection Agency, Region 4. EPA's program seeks to fund efforts to enable agriculture to transition from reliance on pesticides targeted under the Food Quality Protection Act (FQPA).

The strategic planning workshops build on an earlier workshop held in May of 2000 and supported by the U.S. Department of Agriculture, which brought together growers, researchers and extension specialists to determine what it would take from a research, education and regulatory standpoint to reduce the use of "high risk" pesticides in sweetpotato production. This workshop developed a comprehensive assessment of research, education and regulatory gaps (USDA 2001).

In October of 2001 and January, February and August of 2002, four workshops were held bringing together over two dozen researchers, extension specialists, growers, processors and a consultant to develop a detailed plan for enhancing pest management research and education efforts in sweetpotato production. Workshop participants were motivated by the fact that the sweetpotato industry is facing the potential loss of materials, such as the organophosphate and carbamate insecticides threatened by implementation of FQPA. In addition, because sweetpotato is considered a minor crop, manufacturers of crop protection products are hesitant to support research for new pest control products that minimize environmental impact. Therefore, research is needed to expand the number, type and performance of pest management tools available to growers.

The strategic planning workshops were designed to provide participants with an opportunity to systematically and collaboratively develop strategies for filling major research and education gaps within disciplines and across all four states. They were designed to bring growers together with researchers and extension specialists to ensure that the research and education strategies developed address growers' needs and concerns. They were also designed to bring in researchers, educators and growers from the Wisconsin Irish potato industry to share how they have approached FQPA transition challenges and to stimulate discussion about tools and methods that can be transferred to southern sweetpotato production systems.

Albeit informal, the workshops spawned the Sweetpotato Research and Education Industry Coalition (SREIC), which will seek to function as an organizing vehicle to coordinate fundraising efforts, collaborate on research and education projects and disseminate information. Eight individuals, including three growers and representatives of each state and pest management research discipline, currently serve on an ad hoc executive committee.

Pesticides Potentially Targeted for Regulation

Several materials important to sweetpotato growers may be subject to regulatory action under FQPA. Table 1 lists most of the pesticides registered for use in either or both North Carolina and Louisiana sweetpotato production. Group 1 pesticides, as identified by EPA, are a high priority for regulatory scrutiny. Group 1 pesticides registered for use on sweetpotatoes include a number of insecticides and fungicides/nematicides and one herbicide. These are: aldicarb (Temik), carbaryl (Sevin), chlorpyrifos (Lorsban), endosulfan (Thiodan or Phaser), ethoprop (Mocap), methyl parathion (PennCap M), phosmet (Imidan) thiabendazole (Mertect 340-F), dacthal (DCPA). Other pesticides (Groups 2 & 3) have been identified by EPA, but were a lower priority for review.

Table 1: Pesticides Registered for Use on Sweetpotatoes in North Carolina[1] and/or Louisiana[2]

Type	Example Target Pest(s)	Active Ingredient	Trade Name(s)	FQPA Target[3]
Insecticides				
	Aphids, flea beetles, leafhopper	Imidacloprid	Admire	Group 3
		Thiomethoxam	Platinum	NL
	Armyworm, looper, thrips	Spinosad	Spintor	Group 3
		Tebufenozide	Confirm	Group 3
	Flea beetle, cucumber beetle, looper	Carbaryl	Sevin	**Group 1**
		Endosulfan	Thiodan, Phaser	**Group 1**
		Phosmet	Imidan	**Group 1**
	Flea beetle, wireworm	Chlorpyrifos	Lorsban	**Group 1**
	Fruit fly	Pyrethrins	Pyrenone	Group 2
	Leafhopper, tortoise beetle	Malathion	various	Group 3
	Looper	*Bacillus thuringensis*	Condor, Cyrmax, Dipel	NL
	Sweetpotato Weevil	Methoxyclor	Marlate	NL
		Penncap M	Methyl Parathion	**Group 1**
		Bifenthrin	Capture	Group 2

[1] North Carolina State University, *2002 North Carolina Agrichemicals Manual*, College of Agriculture and Life Sciences, http://ipm.ncsu.edu/agchem/cover.pdf (viewed May 29, 2002).
[2] Personal communication with Abner Hammond, Extension Entomologist, Louisiana State University, Baton Rouge, Louisiana, May 31, 2002.
[3] U.S. Environmental Protection Agency, http://www.epa.gov/fedrgstr/EPA-PEST/1997/August/Day-04/p20560.htm

Table 1 Continued.

Type	Example Target Pest(s)	Active Ingredient	Trade Name(s)	FQPA Target
Fungicides/ Fumigants				
	Nematodes	Dichlorpropene	Telone II	NL
		Metam-Sodium	Vapam, Sectagon, Busan	Group 2
		Chloropicrin		Group 2
			Telone C-17, Telone C-35	NL
		Aldicarb	Temik	**Group 1**
		Oxamyl	Vydate	NL
	White grubs	Ethoprop	Mocap	**Group 1**
	Storage house sanitation	Methyl bromide		Group 2
	Bedding root decay, scurf, black rot, foot rot, sclerotial blight	Thiabendazole	Mertect	**Group 1**
		Dichloran	Botran	Group 2
	Post harvest sanitation	Calcium hypochlorite		NL
Herbicides				
	Annual & perennial grasses	Glyphosate	Roundup	Group 3
	Nutsedge	EPTC	Eptam	NL
	Annual grasses & broadleaf weeds	Clomazone	Command	NL
		DCPA	Dacthal	**Group 1**
		Napropamide	Devrinol	NL
	Annual & perennial grasses	Clethodim		NL
		fluazifop	Fusilade	NL
		Sethoxydim	Poast	NL

Key to FQPA Target Groups

EPA has placed FQPA targeted materials into three groups (EPA 1997). EPA is currently reviewing Group 1, which will be followed by Group 2 and then Group 3. **Group 1** = pesticides, which based on the best available information to date, appear to pose the greatest risk to the public health. In making the determination as to which pesticides appear to pose the greatest risk to public health, EPA attempts to take into account exposure to infants, children, and other sensitive subpopulations. Group 1 pesticides include, but are not limited to: 1) organophosphate, carbamate, and organochlorine classes, and 2) probable human (groups B1 and B2) carcinogens, and possible human (group C) carcinogen. **Group 2** = pesticides identified as: 1) possible human carcinogens and 2) materials subject to re-registration. **Group 3** = pesticides, including biological pesticides, that need to be re-registered. **NL** = Not listed.

A Coalition Vision for Sweetpotato Production Systems

An effective strategic plan begins with a vision. Workshop participants developed the following vision for a Sweetpotato Research & Education Information Coalition (SREIC):

SREIC will be the premier sweetpotato research education and industry coalition around the world that will:

- Proactively implement research that promotes environmental stewardship to meet the needs of farmers, consumers, and environmentalists and other related industries.
- Provide reliable and timely information to clientele through unbiased University research and Extension educational programs.
- Develop, coordinate, and adopt throughout the industry new and improved IPM strategies, which can be applied to improve sweetpotato production and marketing.
- Maintain and improve overall sweetpotato quality, attractiveness, and nutritional value.
- Leverage our knowledge base and expertise to gain consistent funding and support to address current and future challenges of sweetpotato stakeholders.
- Increase production efficiency for improved grower profits and competitiveness in national and international markets.

Pest Problems & Knowledge Gaps

Sweetpotato production is challenged by numerous pests. The potential loss of widely used materials raises the question of what additional knowledge and experimentation is necessary to formulate alternative pest control strategies. The following descriptions attempt to summarize the major knowledge gaps within each discipline.

Entomology

At least eight insect pests cause significant yield and quality effects in sweetpotato production. Workshop participants identified the following insect pests as the most important for management: 1) wireworms, 2) white grubs, 3) sweetpotato weevil, 4) sweetpotato flea beetle, 5) cucumber beetle, 6) white fringed beetle, 7) armyworm/cut worm complex, and 8) sugarcane beetle. Some of these pests are problematic only in certain states. Specifically, wireworms and flea beetles are primarily a problem in NC and weevils are primarily a problem in LA and MS. The major barrier to the development of reduced-risk strategies for insect management is that most of the pests do their damage at the larval stage while in the soil and thus population levels are difficult to monitor and predict.

These insect pests and the primary method of treatment are briefly described below. While there are, in many cases, sweetpotato cultivars available with resistance to some of these pests, this does not include Beauregard, the main cultivar used for commercial production. States where the pest is prominent are included in parentheses.

Soil-Borne Insects

Wireworm (NC)

There are several species of wireworm (tobacco wireworm, southern potato wireworm, gulf, and corn). Wireworms feed on the roots and are currently controlled with an application of a soil insecticide, such as Lorsban, Diazinon, Endosulfan or Sevin (USDA 2001).

White grub (All States)

White grubs are sporadic pests; however, they can cause heavy damage when present in a field. Many species of the pest exist and there are many hosts. White grubs feed on the roots are controlled by pre-plant applications of soil insecticides such as Lorsban, Diazinon, Endosulfan or Sevin (February 2001 Strategic Plan).

Sweetpotato Weevil (LA, MS, AL)

Sweetpotato weevils are pests in fields and in storage. Growers typically use a pre-plant application of Imidan, Malathion, Endosulfan, Carbaryl, Diazinon or Methyl Parathion to control this pest in the field (USDA 2001). In Louisiana, a sweetpotato weevil eradication program is in place.

Sweetpotato Flea Beetle (NC)

Adult flea beetles feed on the surface leaves and the larvae feed on roots. Typical treatment includes a Lorsban pre-plant application.

Banded Cucumber Beetle (All Four States)

Banded cucumber beetle lays eggs in the fields and the larvae create small holes in the roots. Cucumber beetle can be a problem in all four states. Typically growers control this pest with a pre-plant application of Lorsban or Mocap. In some cases, methyl parathion is applied to control adult beetles.

White Fringed Beetle (All Four States)

White fringe beetles have one generation per year and their larvae feed on the roots. They are difficult to control and no insecticides are specifically registered for their control. They occur sporadically in North Carolina and can be a major pest in Alabama, Louisiana and Mississippi.

Foliar Feeding Insects

Lepidoptera (All Four States)

Lepidoptera (e.g., cabbage loopers, beet armyworms, corn earworms) are sporadic pests of sweetpotato that usually arrive in large numbers and control is necessary. Typically growers apply methyl parathion, malathion, carbaryl, Lannate or *Baccillus.thuringiensis*.

Sugarcane Beetle *(*LA)

Sugarcane beetle adults feed underground and are difficult to control using chemical treatments. Pyrethroids are effective but only if the material can reach the adults.

Major Issues & Knowledge Gaps

Workshop participants identified several major knowledge gaps and needed areas of research in sweetpotato insect management. To begin, there is a lack of effective scouting and monitoring techniques, particularly for soil-borne insects, including wire worms, white grubs and spotted cucumber beetle. Without these techniques, growers have a hard time determining the level of pest pressure. In addition, there are few economic thresholds for pests, making it difficult for growers to determine when and if control tactics are necessary.

Furthermore, in a number of cases, remedial controls, such as registered pesticides or other control strategies, are not available to manage pests that emerge later in the growing season. Without effective monitoring techniques, economic thresholds and remedial management strategies, growers rely on preventive soil insecticide treatments prior to planting.

In addition, there is a limited understanding of basic pest biology, population dynamics and field conditions (e.g., soil type, soil moisture, cultivar, cropping history, etc….) necessary to correlate insect damage with causal factors. This makes it difficult for growers to predict with any accuracy and assurance which fields are likely to require management. It further impedes the development of effective cultural controls.

Lastly, there are limited commercially viable cultivars with measurable resistance to insect pests. While some cultivars have resistance to selected pests, most buyers currently purchase Beauregard, a variety of sweetpotato which is highly susceptible to insect damage.

The major knowledge gaps for sweetpotato insect management are identified in Table 2. Shaded areas indicate high priority research topics.

Table 2: Insect Management Knowledge Gaps: Priority Areas for Research

Insect	Knowledge Gap				
	Sampling & Monitoring Techniques	**Economic Thresholds**	**Causal Agents**	**Resistant Cultivars**	**Remedial Controls**
Wire worms	High (for larvae)	Medium	High	Medium	Medium
White grubs	High (for adults and larvae)	High	High	Medium	High
Sweetpotato Weevil	Low	Low	Low	Medium	Low
Flea Beetles	High (for larvae)	High	High	Medium	High
Cucumber Beetle	Medium	High	High	Medium	High
White Fringe Beetle	Medium	High	High	Medium	High
Sugarcane Beetle	Medium	High	High	Medium	High
Lepidoptera	Low	Low	Low	Medium	Low

Plant Pathology

Viruses, fungi, bacteria, and nematodes cause significant disease problems in commercial sweetpotato production. These pathogens and their primary control strategies are described below.

Viruses

Over the last several years, disease management in sweetpotato has taken a tremendous leap forward following the development of virus-indexed seed programs. It appears at present that reductions in yield and quality in commercial production occur as a result of the interaction of multiple potyviruses (Clark 2002). Sweet potato feathery mottle virus (SPFMV) has long been recognized to occur wherever sweetpotatoes are grown. In the last two years, it has been determined that Sweet potato virus *G* (SPVG) and another as yet unnamed potyvirus occur in combination with SPFMV. SPFMV and SPVG are transmitted by aphids while the vector for the third virus is unknown. They are currently managed by use of virus-tested seed, but means of reducing re-infection of healthy seed need to be developed.

Fungi and Bacteria

A number of fungi present chronic disease problems in sweetpotato production. These include foot rot, black rot, Fusarium root rot and stem canker, scurf, Sclerotial blight and Rhizopus soft rot. Foot rot, black rot and scurf are adequately controlled through sanitation procedures, including the use of disease-free seed. Seed treatment with dicloran and/or thiabendazole in plant beds is often used to control Rhizopus soft rot. However the economic value of this treatment has been questioned and is worthy of examination. There are no currently registered alternatives to dicloran.

'Beauregard' storage roots are susceptible to bacterial root and stem rot, caused by the bacterium *Erwinia chrysanthemi*. This disease can cause stem rot in the field, which may result in reduced plant stands and reduced yield of surviving plants. Furthermore, it can cause soft rot of roots in storage, in market, and in plant beds (Clark 2002). Bacterial stem and root rot is managed primarily through strict sanitation. This includes the use of disease-free planting material and other handling practices that minimize the potential for introduction and spread of the bacterium. Although farmers avoid seed known to be infected with this pathogen and follow common sense approaches to avoiding conditions, such as oxygen depletion, which favor disease development, control programs have not been developed.

Nematodes

Two nematodes can cause serious losses in sweetpotato in the southeastern U.S., root-knot nematode, *Meloidogyne* spp., and reniform nematode, *Rotylenchulus reniformis*. Aldicarb (Temik) and 1,3-dichloropropene (Telone) are commonly used for managing nematodes on sweetpotatoes. Cultural controls such as sanitation and crop rotation are also common grower practices, but cannot be relied upon as a sole means of nematode management.

Postharvest Diseases

Four diseases can occur commonly on sweetpotato in storage, transit or market: Rhizopus soft rot, bacterial root and stem rot, Fusarium root and stem canker, and Java black rot. All four pathogens can enter the roots through wounds. Thus curing roots immediately after harvest provides a good measure of control of each disease in storage (Clark 2002).

Rhizopus soft rot has accounted for the majority of postharvest disease control measures practiced, especially the widespread use of the fungicide dicloran, which is commonly applied to sweetpotatoes as a dip or spray treatment as they are being packed for shipment to market. Since this is applied directly to the consumed product after it is washed, it is reasonable to expect that it constitutes the primary pesticide residue on sweetpotatoes in the market.

Major Issues & Knowledge Gaps

The major stumbling block to developing new, reduced-risk disease management methods is a limited understanding of which pathogens are causing significant loss of yield and quality. In this regard, workshop participants are particularly concerned about the lack of information pertaining to: 1) the effect of specific pathogens on production, 2) the extent of root damage caused by particular pathogens, and 3) the relationship between specific pathogens and rejected product shipments. Additional knowledge gaps include an inadequate understanding of: 1) how selected pathogens are spread, 2) population dynamics of pathogens and vectors, 3) economic thresholds, particularly for nematodes, 4) buyer practices, including which diseases are present and how much must be present for a shipment to be rejected, and 5) the efficacy of existing materials.

The lack of information on the yield and quality effects of specific pathogens is particularly acute with viruses and postharvest diseases. For example, about 20 viruses have now been described from sweetpotato, but other than SPFMV, it is not clear how many of these viruses occur in the U.S. (Clark 2002). Virus-indexing programs were initiated, of necessity, before research on identification of viruses and their effects on production were completed.

A similar situation exists for post-harvest diseases. Currently, when a shipment of sweetpotatoes is rejected by the buyer, the specific cause for the rejection (i.e., which disease) is not determined. It is unclear what losses Rhizopus soft rot and bacterial root rot actually cause in transit and in the market and there is little feedback on how much disease must be present in a shipment to cause buyers to reject it. Furthermore, new infections can occur when sweetpotatoes are removed from storage, washed and packed. Thus alternatives are needed to control diseases at this stage.

Disease transmission is a needed area of research. For example, potyviruses are spread by aphids and other sweetpotato viruses by whiteflies, however, there is little understanding of how these insects spread the viruses. A better understanding of aphid and whitefly population dynamics would help identify whether it is feasible to reduce reinfection by viruses by controlling aphid and whitefly vectors. Little is known about the spread of the bacterium, *E. chrysanthemi* (e.g., via fruit flies in storage or by cutting plants).

Economic thresholds are not developed for most disease problems and control tactics are generally prophylactic in nature. Economic thresholds would be particularly useful for nematode control where there is currently a lack of published research to establish thresholds for either root-knot or reniform nematode. In order to develop thresholds that reflect different soil types and cultivars, more information is needed about nematode distribution in soils.

The efficacy of some materials routinely relied upon by growers and packers should be examined. For example, packers rely heavily on dicloran to control post-harvest diseases. While dicloran is active against Rhizopus soft rot, it may not be providing the level of control of this disease that growers expect and does not provide control of bacterial root rot. There also is some question regarding the efficacy of 1,3-dicloropropene, which is applied prior to planting for nematode control.

Preventive practices are an important area in need of exploration. This includes evaluation tools to determine seed health and whether latent infections are present before planting. In addition, postharvest practices can contribute to disease and decay during storage, transport and market.

Table 3 displays how workshop participants ranked needed areas of research to fill existing disease management knowledge gaps.

Table 3: Disease Management Knowledge Gaps: Priority Areas for Research

Pathogen	Knowledge Gaps				
	Pathogen Effects on Yield & Quality	**Mechanisms of Transmission**	**Economic Thresholds**	**Efficacy of Selected Materials**	**Preventive Practices**
Viruses	High	High (potyviruses)	Low	Low	High (seed health evaluation)
Bacteria & Fungi	High	High (*Erwinia chrysanthemi*)	Low	Medium (fungicides used in seed beds)	Medium *(Erwinia chrysanthemi)*
Nematodes	Low	Low	High	High	Low
Post-Harvest Diseases	High	Medium	Low	High (Botran)	High (curing practices)

Weed Science

Workshop participants identified the following major weed species in need of further investigation: nutsedge (purple, yellow, rice flats), pigweed, annual grasses, sicklepod, sesbania, and ground cherry nightshade. Other weed species also worth review include morningglory species, lambsquarters, cocklebur, perennial grasses (Johnson grass, Bermuda grass), s. sandspur, common ragweed, prickly sida.

Growers typically apply herbicides to plant beds to control annual weeds. Broadleaf weeds are more difficult to control with herbicides. In fields, growers use pre-plant tillage and cultivate at least three times during the growing season. Fields are also hand-weeded at least once. In general, growers perceive there to be relatively few weed management tools.

Weeds are slightly more common in sweetpotato plant beds than in fields. Weeds in plant beds can reduce plant numbers and weight. Fields with severe weed infestations can dramatically reduce yields as well as diminish sweetpotato root quality and interfere with harvest (USDA 2000).

Major Issues & Knowledge Gaps

The development of reduced risk strategies for weed management is challenged by several factors. There is a general lack of understanding of which weed species are in growers' fields and which present the greatest threat to production. Additionally, there is limited information about the basic biology of hard to control weed species, particularly sedges and Palmer amaranth. Understanding the basic biology of various weeds could enhance control using either cultivation and/or chemical methods. Understanding interactions with other pests such as insects may be critical in reducing root damage. In addition, if the impact of weeds is negligible at certain times during sweetpotato development, it could result in reduced herbicide application and cultivation, which translates into both economic and environmental benefits.

There is limited information about causal factors related to the density and diversity of weeds in fields. These factors could include but are not limited to: 1) the interaction between weeds, insects and diseases, 2) crop history, 3) planting date, and 4) soil and moisture conditions. Information on mechanical controls is limited, including the timing and frequency of cultivation, mowing, and hand-weeding. Cultural practices such as reduced-tillage and cover crops have received limited attention. Evaluation of new materials is also warranted and as is an investigation of critical "weed free" periods.

Table 4 lists the major knowledge gaps for weed management.

Table 4: Weed Management Knowledge Gaps

▪ Identity of major weed species currently in grower fields.
▪ Causal factors, particularly the impact of planting date, soil and moisture conditions and the interaction between insects, weeds and diseases.
▪ Efficacy of mechanical controls, specifically cultivation.
▪ Efficacy of cultural controls, specifically reduced-tillage and cover crops.
▪ Critical weed-free periods.
▪ Efficacy of new herbicides.
▪ Basic biology of Palmer Amaranth and nutsedges.
▪ Canopy development and density of new Beauregard varieties.

Host Plant Resistance

Major Issues & Knowledge Gaps

Host plant resistance (HPR) is the foundation of an effective IPM program and it is one of the most attractive preventive methods for controlling insect and disease problems in sweetpotato. Disease resistance has been used to successfully reduce losses in sweetpotato production caused by fusarium wilt, internal cork, and russet crack, and Streptomyces soil rot (Clark 2002). Host plant insect resistance in sweetpotato has been documented in the literature (Collins et al. 1991, 1999, Mao et al. 2002, 2001a, and 2001b) but remains non-existent in commercially acceptable cultivars despite years of research and breeding. Mao et al., (2001) demonstrated that weevil resistance existed in several breeding lines from the USDA, U.S. Vegetable Laboratory. Yet, this later work documents the complexities of quantifying insect resistance. Genotypes did vary in susceptibility, but storage time and the environment greatly affected resistance to the sweetpotato weevil.

Traditionally, the U.S. sweetpotato industry has been dominated by a single cultivar at any point in time—Centennial in the 1960's, Jewel in the 1970-80's and Beauregard since 1990. 'Beauregard' was adopted by the industry because it produced a uniformly high yield of attractive sweetpotatoes. 'Beauregard' remains highly susceptible to a number of economically important insects and pathogens, including wireworms, banded cucumber beetle, white grub, white-fringe beetle, sugarcane beetle, root-knot nematode and bacterial root rot and bacterial soft rot (Clark 2002).

There are opportunities for using resistance to improve control of diseases and insects. Workshop participants identified opportunities for developing sweetpotato cultivars that are: 1) less susceptible to the WDS (wireworm, *Diabrotica*, *Systena*) complex of soil insects and thus could help reduce prophylactic insecticide use and 2) resistant to Rhizopus and thus that could result in fewer postharvest fungicide applications.

The challenge, however, is to combine resistance traits with horticultural characteristics competitive with 'Beauregard'. For example, the only recognized sources of resistance to viruses are in genotypes that are far from horticultural acceptability (i.e. poor yielding with white-fleshed, higher dry matter storage roots). Furthermore, no source of resistance has been identified for reniform nematode. Two decade old cultivars, 'Excel' and 'Resisto', have quantifiable levels of insect resistance to the WDS soil insect complex and may represent economically significant sources of partial resistance (Jones et al. 1989, Jones et al. 1983**),** but this resistance has not been incorporated in cultivars grown commercially on a large scale.

The major barrier to the development of resistant cultivars is the long term nature of traditional breeding programs and the controversy surrounding non-traditional, transgenic methods. A traditional breeding program can take over 10 years to develop a cultivar with the desired traits and insect resistance. Transgenic approaches might offer technical possibilities in minimal time, but have not been employed in sweetpotato for a variety of reasons. Another alternative might be the use of low rates of environmentally 'friendly' chemicals to induce enhanced systemic resistance. Several compounds have been tested on other crops and one, Messenger produced by Eden Biosciences, has been sold for commercial use in sweetpotato. Unfortunately, there is a lack of research on sweetpotato in this area and there are no published evaluations of any of this class of chemical for disease control in sweetpotato.

In the short term, there is breeding research that can be pursued to develop improved breeding tools. Traits can be improved via mass selection in sweetpotato, i.e., progeny possessing favorable levels of a given trait (the upper 10 %) are recombined. This cycle is repeated until goals are achieved. This process can effectively be used to enhance resistance to rhizopus soft rot, souring, bacterial soft rot, and viruses.

Enhancing insect resistance is more daunting, but even minimal levels of resistance may enable producers to reduce pesticide inputs. New genomics-based tools are also providing new breeding methods that can be applied in a conventional breeding program to develop insect resistant sweetpotatoes in shorter time. For example microarrays which consist of sets of hundreds to thousands of expressed genes printed onto a single specialized slide, may enable us to identify genes that have been found to be universally important in plants for "general" and "specific" forms of pest resistance. These resistance (R genes) could then be identified in NCSU's recently developed sweetpotato BAC library, cloned and combined (stacked) via molecular marker-assisted breeding into cultivars which may provide greater levels of resistance than currently known.

Using DNA-based molecular markers to map the locations of economically important traits is another potentially valuable breeding tool that can be used to select and develop new disease and insect resistant varieties. For example, this tool is particularly valuable in identifying U.S. germplasm resistant to the African Sweetpotato Viral Disease (SPVD) as an appropriate strategy to develop resistance without actually having the severe SPCS strains in the U.S. Microarrays may also enable us to better understand cultivar decline in sweetpotato and to certify plant stock entering foundation seed programs is genetically free of mutations. The sweetpotato breeding programs at LSU and NCSU both have small but active collaborative programs in all of the above mentioned research areas. However, additional funding is needed if genomics tools are employed for the development of insect and disease resistant sweetpotatoes. This is because genomics, while being very powerful and precise, are very costly to implement.

Goals and Tactics

The workshops illuminated the real and urgent need for significantly more resources to pursue both basic and applied research. There was a general agreement that there is a dearth of research focused on basic pest biology, particularly for pathogens and soil-borne insects. A better understanding of pest life cycles and relationships to potential causal agents such as soil and climate conditions, cropping history, and cultivar selection is necessary to develop basic IPM tools. However, at the same time, growers have a very real and immediate need for pest control products and approaches that are more effective than current techniques and work as replacements for FQPA-targeted materials.

The workshops revealed that while grower education is and will remain an important component of pest management programs in sweetpotatoes, the focus right now needs to be on enhancing research efforts so that new and improved techniques can be made available to growers. Furthermore, there was considerable discussion about the need for SREIC to engage in the IR-4 process to enhance opportunities for testing and registering reduced-risk products in sweetpotatoes. This was seen as a high priority by all.

Participants were asked to develop action plans for high priority research and education areas. These action plans are presented below in Table 5. Action plans first identify the overarching goal and then articulate a particular strategy to achieve that goal. Possible and suggested activities are identified for each strategy as well as the principal people interested in implementing the activities. A suggested amount of time for each strategy is included. Some action plans are cross-cutting in nature and may be best tackled using a multi-disciplinary approach.

Table 5: Pest Management Goals, Strategies and Activities

Insect Management				
Goal	**Strategy**	**Activities**	**Time Frame**	**Primary People**
Enhance grower decision-making and minimize prophylactic insecticide applications and costs	Develop and implement grower advisory based on identification and weighting of causal agents	• Identify fields in each state to leave untreated strips. • Develop data-collection protocol. • Collect and analyze data; aim for 300-400 data points. • Identify causal agents. • Develop scoring system to identify high, medium and low risk fields. • Develop outreach materials and implementation strategy.	3-4 years	JR, RS
	Improve sampling and monitoring techniques for select insects	• Develop sampling techniques for soil-borne insects, particularly wireworms (larvae), white-grubs (adults and larvae) and flea-beetle (larvae).	2 years	RS, AH, MW, KS
	Determine spatial and temporal distribution of adults and / or larvae	• Survey adults and/or larvae of soil borne insects utilizing sampling and monitoring techniques.	1 year	RS, AH, MW, KS

Table 5 Continued.

Insect Mgmt Continued				
	Strategy	**Activities**	**Time Frame**	**Primary People**
	Develop economic thresholds & relate survey results to root damage.	• Analyze root damage and survey data for selected species.	1 year	RS, AH, MW, KS
Identify additional insect management strategies	Evaluate efficacy & spray efficiency of new insecticides, including those applied mid-season	▪ Conduct efficacy trials for various materials, including: o White Grub—*Aztec, Regent, Capture*	2 years	RS, MW
Disease Management				
Goal	**Strategy**	**Activities**	**Time Frame**	**Primary People**
Enhance grower decision-making and minimize unnecessary post-harvest fungicides	Identify specific pathogens responsible for rejected loads by systematically surveying and investigating rejected loads	▪ Develop protocol to ID pathogens and standardize for all institutions.	2-3 years	AH, GH, CC, WC

Table 5 Continued.

Disease Mgmt Continued				
		Activities ▪ Round robin spiked sample & unknown to determine similar extraction efficiencies. ▪ Prepare grower survey form concerning economics (e.g., value of load, dumping & re-packing costs, shipping expense & % of load lost). ▪ Identify at least one grower in each state to fill out form and send in sample of roots from rejected load. ▪ Compile data within each state and across states and publish report. ▪ Prepare grower education bulletin about how to anticipate rejected loads and adjust packing and storage practices.		
Identify efficacious post-harvest treatments	Develop tools to evaluate efficacy of different treatments for control of specific diseases	▪ Obtain survey results pertaining to rejected loads. ▪ Develop assays or mechanisms for detection for most important diseases/abiotic factors (e.g., Erwinia, including latent infections and secondary infections in packing).	2 years	**GH, CC, AH** **GH, CC, AH**

Table 5 Continued.

Disease Mgmt Continued				
		Activities		**Primary People**
		▪ Develop standardized protocols for evaluating efficacy of potential treatments on specific diseases (e.g., Botran, chlorine, ozone, hot water, peroxide, cultivar resistance).		**GH, CC, AH**
Enhance grower access to healthy propagation materials	Develop tools to determine seed health	▪ Compile list of problems (e.g., viruses, fungi, bacteria, mutations, abiotic, etc…). ▪ Survey to determine incidence of particular disease problems (% damage) and rank problems according to their importance. ▪ Develop detection techniques for highest ranked problems; work with entomologists to validate and verify techniques. ▪ Publish results and develop grower guide, including visual aids for disease identification.	2-3 years	**CC, GH**

Table 5 Continued.

Weed Management				
Goal	**Strategy**	**Activities**	**Time Frame**	**Primary Person**
Focus research and education efforts on highest priority weed problems	Identify highest priority weed problems and current management practices	Develop and tabulate results of grower survey to include: ▪ Questions pertaining to most troublesome weed species and current weed management practices. ▪ Develop visual aids to assist with weed ID.	1 year	**MC** **BL, JS** **DM**
Enhance grower decision-making tools and reduce weed management hosts	Identify "density thresholds" (i.e., "weed-free" periods) for key weed species	Conduct studies on farms and in research plots to determine critical periods of control for most troublesome weed species, particularly P amaranth and nutsedge.	2 years	**DM**
	Identify causal agents and new management strategies that can be evaluated	▪ Identify weedy fields utilizing GPS technology. ▪ Survey growers to determine crop history and production practices for weedy fields. ▪ Obtain sweetpotato samples from weedy fields at harvest and determine insect & nematode damage. ▪ Determine conditions (e.g., temperature and moisture) which favor the growth and development of weeds, particularly P. amaranth and nutsedge.	3 years	**MS, DM**

Table 5 Continued.

Weed Mgmt. Continued				
		Activities ▪ Collect weed seed from different states to determine if there are different species biotypes. ▪ Identify several weed-free sample areas for comparison, preferably within the same field.		
Enhance grower access to non-chemical weed management techniques	Identify and evaluate mechanical weed control practices	▪ Establish field research to evaluate percent weed control, plant injury, and sweetpotato yield for various individual and combination mechanical treatments, including: rolling cultivator, chopper, hipper, rotary mower, hand weeding, hoeing, wick-bar alone and wick-bar with glyphosate.	2 years	**DM**
Increase registration of herbicides for control of key weed species	Identify and evaluate performance of selected materials in all four states	▪ Conduct efficacy and residue trials to evaluate the performance of Carfentrazone, Sulfentrazine, Halosulfuron, Metolachlor and Dimethanamid. ▪ Seek registration of potential candidates through IR-4 Program.	2-3 years	

Table 5 Continued.

Plant Breeding				
Goal	**Strategy**	**Activities**	**Time Frame**	**Primary Person**
Develop genomic tools to facilitate sweetpotato breeding	Identify important genetic markers linked to virus resistance; genes conferring resistance to pests; screening protocol for undesirable mutant clones in foundation plant stock	▪ Develop linkage map of Beauregard x virus resistant Tanzania based on DNA markers. ▪ Develop BAC library resource for sweetpotato to identify resistance (R) genes. ▪ Develop a microarray approach to surveying the sweetpotato genome for inactivation of important genes, signaling the presence of major mutations.	3-5 years	CY
Develop germplasm resistant to rhizopus soft rot & potentially eliminate Botran use	Combine resistant germplasm with elite breeding material for commercially acceptable cultivars	▪ Mass selection nurseries to develop rhizopus soft rot resistance in commercially acceptable cultivars.	1 year	DL
Enable reductions in insecticides used for Diabrotica control.	Develop varieties less susceptible to WDS insect pests.	▪ Screen early lines in multiple sites to identify lines less susceptible using std. proc. and R & S checks by state ▪ Distribute best lines identified by each program to cooperators and evaluate resistance to WDS using std. proc. and R & S to multiples sites. ▪ Develop breeding strategies to improve resistance to WDS. ▪ Evaluate best lines in lesser scale trials under reduced insecticide	8-12 years	CY DL MJ

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